

Potential of Renewable Energy from Waste Mitigation of Gas Emissions of CH₄ and CO₂ in Bontang City, East Borneo

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Abstract—The study is aimed to determine the potential of electrical energy from the mitigation of greenhouse gas emissions, mainly methane (CH₄) and carbon dioxide (CO₂) based on the composition of municipal waste generated in Bontang City of East Borneo. The research was conducted by calculating the emissions of methane (CH₄) and carbon dioxide (CO₂) using Intergovernmental Panel on Climate change (IPCC). The calculation results show that the composition of organic waste consists of 482,105 tons/year of methane (CH₄) and 132,579 tons/year of carbon dioxide (CO₂) gas emission production. Overall, the composition of municipal waste generated are 1,090,380 million tons/year of CH₄ and 299,854 tons/year of CO₂. The conversions of produced gas mitigation into electricity are about 28,786,022 kWh/year of CH₄ and 749,636 kWh/year of CO₂.

Keywords—renewable energy; waste mitigation; gas mitigation; CH₄ and CO₂ emissions

I. INTRODUCTION

It is well-known that methane (CH₄) gas has become a serious threat to the environment and contributed to the greenhouse gas problems [1]. As the potential gas for global warming, methane gas has caused detrimental impact on health, vegetation and crops, human for the last 20 years period. One ton of methane gas may cause 72 times more warming Earth temperature than a ton of carbon dioxide (CO₂). Therefore, mitigation of CH₄ from landfills is highly necessary either in terms of the formed carbon dioxide (CO₂) conversion or the added value of a landfill with utilizing of CH₄ gas into electrical energy [2].

High depending on conventional energy generation, such as fossil fuel from oil, gas and coal in order to meet the electric energy demand is directly contributed to the increase in greenhouse gas emissions. Mainly, the conventional power plants release much CO₂ gas into the atmosphere that causes global temperature increase due to the disruption of the carbon cycle in the atmosphere [3]. The potential for solid waste to capture CH₄ gas can reduce the potential for greenhouse gas emissions by utilizing the gas methane for power generation. In this regard, it is important to estimate the potential emissions of CH₄ from waste disposal. Methane is commonly used as a source of energy in many parts of the world [4], [5]. However, the utilization of biogas which is environmentally friendly may eliminate the emissions of CH₄. Nevertheless, the methane gas is one of the most influenced greenhouse gaseous which is 20 times more harmful than carbon dioxide regarding the greenhouse effect [6], [7].

Methane emission reduction strategies offer one of the most effective means of mitigating global warming. The role of international cooperation in reducing methane and other short-lived climate forcers are very important. Because air quality benefits and the climate improvement from CH₄ mitigation will be experienced globally, the efforts to reduce methane gas emissions in one country will benefit to others [8], [9]. In many countries, the available data on waste generation are not consistent, leading to a large uncertainty in the estimation data. Previous studies have been conducted with the method of garbage disposal; however, their approaches are not using trench method from sanitary landfill [9], [10].

The main objective of this paper is to recommend the possible methane abatement strategies and to quantify methane emissions that may be generated from sanitary landfills in Bontang City of East Borneo within the period between 2005 and 2016. In this study, the Intergovernmental Panel on Climate change (IPCC) as default method (DM) is used to estimate the potential methane gas from the disposal sites.

II. CASE STUDY

The landfill of Bontang Lestari is located in the village of Bontang Lestari as the location of the waste disposal generated from community activities in Bontang City. Geographically, Bontang City is located between 117°021' and 117°029' of East Longitude and between 0°001' and 0°011' of North Latitude with the potential level of solar radiation is large enough around 4.8 kW/m²/day [11]. The solar radiation is very important aspect in natural biomass technology, such as landfill waste disposal. Accumulation of waste in the landfill of Bontang Lestari is processed using sanitary landfill. The land area is planned to be used for waste disposal is approximately 10 h.a. Landfill might be described as vacant land which is planted with shrubs and bushes. The landfill characteristic in this area is quite unique regarding to the environmental aspects because the landfill location is surrounded by the protected forest area, the plains area to the coast and the plantation of hilly sites. The landfill topography can be seen in Fig. 1.

Bontang Lestari landfill of waste final processing is planned to have a height of 16m from the basic plan of land hoarding landfill with an estimated area of 6 hectares. The landfill layout is shown in Figure 2. In this layout, the planned capacity of the landfill of waste generation and the thickness of the landfill will influence the age of the landfill. The thickness of planned hoarding is 16 m. The landfill is designed to be able to accommodate Bontang Lestari waste up

to 960,000 m³. Regarding the landfill capacity and the amount of waste, the Bontang Lestari landfill might be utilized as waste disposal location until 2020 with a thickness of 16 m. From this information, the volume of waste that might be converted into useful energy is potentially high.

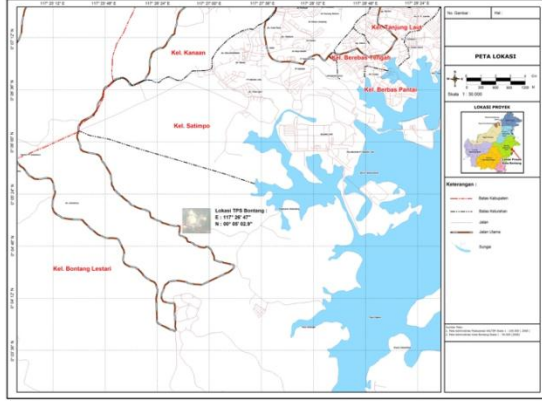


Figure 1. Map location of Bontang landfill

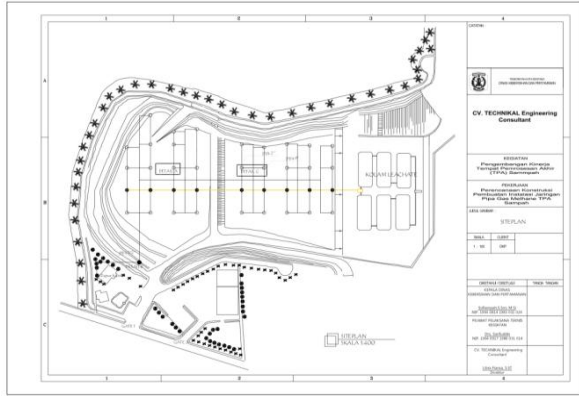


Figure 2. Installation layout of Bontang landfill

In this study, the emission factor is defined as representative value that correlates the quantity of pollutants released into the atmosphere from activities related to pollutants. Emission factor can also be defined as a particular Weight of pollutants produced by burning a fuel for a certain period. When the emission factor of a pollutant is known, then the amount of pollutants that escape from the combustion process can be known in amount per unit time. This factor will be used for the calculation and analysis of emission reduction. The factor correlates with the potential mitigation of greenhouse gas emissions, mainly CH₄ and CO₂ based on the characteristics of municipal solid waste generated in Bontang which is adjusted to Guidelines issued by the Intergovernmental Panel on Climate change (IPCC) [12]. The promising implementation in this respect is to have electrical energy output converted from greenhouse gas emissions.

III. METHODOLOGY

The mitigation of CH₄ in the framework of the reduction of greenhouse gases according to the direction of the United

Nations Framework Convention on Climate Change (UNFCCC) has been approved. In this regard, the US - Environmental Protection Agency (EPA) has issued guidelines about the identification, evaluation of landfill and a rough estimation of CH₄. One of the guidelines is through Intergovernmental Panel on Climate Change (IPCC) [2], [13]. The aim of climate change mitigation in the waste sector is to reduce the volume and the concentration of greenhouse gas emissions in the atmosphere so as to create stability in the atmosphere. The formula for calculating the emissions of methane (CH₄) based on the guideline is as follows:

$$ME = \left(\frac{MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16}{12} - R \right) \times (1 - OX) \quad (1)$$

where

- ME* : Methane gas emission in (Gg/year)
- MSW_T* : Masses of garbage that goes into processing or landfills (Gg/year)
- MSW_F* : Percentage of waste that goes to landfill processing or the amount of waste production
- MCF* : Methane correction factor. Currently, Indonesia has gas processing equipment in landfill garbage. The value of 0.4 is arbitrarily selected in the calculations.
- DOC* : Degradation of organic carbon (IPCC)
- DOC_F* : DOC Fraction, namely 0.77 (IPCC)
- F* : Fraction by volume of methane in landfill garbage. IPCC provides standard value of 0.5.
- R* : CH₄ stored in gas processing instrument. Indonesia does not have gas processing instrument from measured methane gas of waste generation, then the R value is set 0.
- OX* : Oxidation factor. IPCC provides a standard value of 0.1.

Meanwhile, the equation for calculating the emissions of carbon dioxide (CO₂) is as follows :

$$CE = ME \left(\frac{1-F}{F+OX} \right) \times \left(\frac{44}{16} \right) \quad (2)$$

where

- CE* : Carbon dioxide gas emission in (Gg/year)

Ref. [14] describes about the converting of methane gas into electrical energy, i.e 1 kg of CH₄ is equivalent to 6.13x10¹⁷ Joule of electric energy. Meanwhile, the electric energy consumption indirectly contributes to both emission of CO₂ and CH₄ and the waste production directly contributes to produce CO₂ and CH₄ in the landfill of Bontang Lestari. The test results are based on the daily electrical needs counted in a year. The amount of CO₂ and CH₄ that are reduced become a baseline plan for small scale standalone hybrid power systems (HPS) application by means landfill gas, photovoltaic (PV) and diesel generator in remote areas.

IV. RESULTS AND DISCUSSION

The increase in waste volume in Bontang due to the population growth. In 2010, the population reached 143,683 inhabitants. This number has increased by 167,094 inhabitants in 2016 and the number trend is increasing every year. The Bontang residents in 2010 and 2016 spread over three sub-districts, namely sub-districts of North Bontang, South Bontang and West Bontang as shown in Table I.

TABLE I. POPULATION OF BONTANG

Sub-District	Total population (People)	
	2010	2016
South Bontang	57,442	65,621
North Bontang	61,394	72,539
West Bontang	24,847	28,934
Total	143,683	167,094

TABLE II. TOTAL WASTE IN BONTANG

Sub-District	Total waste (Liters)	
	2010	2016
South Bontang	143,605	164,053
North Bontang	153,485	181,348
West Bontang	62,118	72,335
Total	359,208	417,735

TABLE III. COMPOSITION OF MSW IN BONTANG

Description	Percentage (%)
Remaining organic food	44.47
Wood, twigs, and leaves	9.03
Paper	13.23
Plastic	11.63
Metal	4.13
Fabrics and textile	3.24
Rubber and leather	5.95
Glass	3.79
Other	4.53

The facts of population growth of Bontang increases, it follows the increase in amount of waste. The assumption to measure the amount of waste by estimating that one resident produces 2.5 liters of waste every day. Using the data of total waste in 2010, the amount of waste in Bontang in 2016 is estimated as shown in Table II. Sub-district of North Bontang has the highest waste volume while the least amount of waste is located in the West Bontang. It is due to the population activities in North Bontang is more dense than in other sub-districts. In this respect, the study has investigated that 167,094 inhabitants in 2016 in Bontang generate a contribution of urban waste 0.5625 m³/person/day. Meanwhile, the composition of waste masses is presented in Table III.

Based on the waste generation and waste composition in Bontang, the volume of gas emission of CH₄ and CO₂ using equations (1) and (2) are calculated. The results of calculation is presented in Figure 3. The composition of Bontang organic trash produces 482,105 tons/year of emission of CH₄ and 132,579 tons/year of emission of CO₂. Furthermore, the composition of the waste paper produces 143,428 tons/year of emissions of CH₄ and 39,443 tons/year of emission of CO₂. Meanwhile, the composition of 11.63% of plastic waste produces 126,082 tons/year of emission of CH₄ and 34,673

tons/year of emission of CO₂. The value of methane emissions and carbon dioxide emission are 97,895 tons/year and 26,921 tons/year, respectively produced from the waste composition of wood, twigs and leaves. Rubber and leather composition of 5.95% produces 70,772 tons/year of emission of CH₄ and 19,462 tons/year of CO₂. The composition of fabrics and textiles 3.24% produces 35,125 tons/year of emission of CH₄ and 9,659 tons/year of CO₂. The composition of Bontang overall garbage produces 1,090,380 million tons/year of methane emission and 299,854 tons/year of carbon dioxide emission.

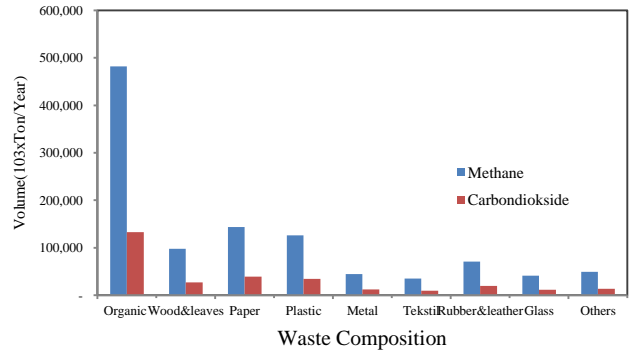


Figure 3. CH4 and CO2 emissions from waste composition

Figure 4 shows the conversion of emission from waste composition into electrical energy. The methane and carbon dioxide gas emissions may produce electric energy 12,772,567 kWh/year and 331,447 kWh/year, respectively. Moreover, the accumulated electric energy of the composition of municipal waste is 28,786,022 kWh/year resulting from the emission of methane and 749,636 kWh/year resulting from the emission of carbon dioxide. The results indicate the promising potential gas emission to be converted into useful energy by means the electrical energy.

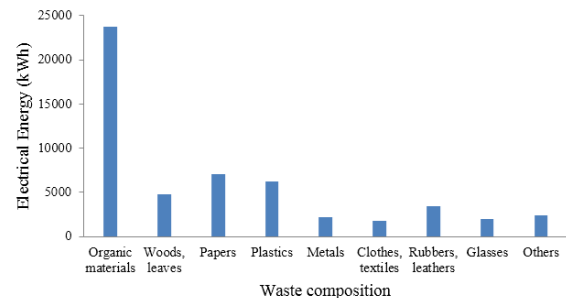


Figure 4. Electrical energy from waste composition

V. CONCLUSION

The study has investigated that 167,094 inhabitants Bontang generate a contribution of urban waste 0.5625 m³/person/day. The composition of organic waste produces methane gas emission by 482,105 tons/year and carbon dioxide emission by 132,579 tons/year. Meanwhile, the waste composition from textile fabric has the lowest value of 3.24% resulting in emissions of methane by 35,125 tons/year and carbon dioxide by 9,659 tons/year. The potential conversion

of the composition of municipal waste produces of electric energy from methane gas and carbon dioxide emissions are 28,786,022 kWh/year and 749,636 kWh/year, respectively. These results can be further evaluated for developing small-scale hybrid power systems in remote location.

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